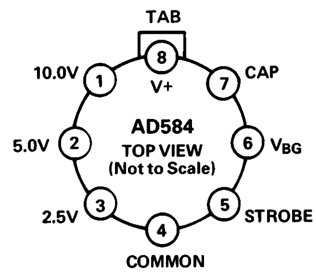
Pin Programmable Precision Voltage Reference

AD584*

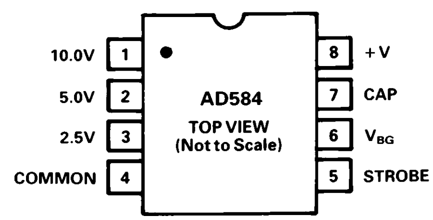
FEATURES
Four Programmable Output Voltages:
10.000 V, 7.500 V, 5.000 V, 2.500 V
Laser-Trimmed to High Accuracies
No External Components Required
Trimmed Temperature Coefficient:
5 ppm/°C max, 0°C to +70°C (AD584L)
15 ppm/°C max, –55°C to +125°C (AD584T)
Zero Output Strobe Terminal Provided
Two Terminal Negative Reference
Capability (5 V & Above)
Output Sources or Sinks Current
Low Quiescent Current: 1.0 mA max
10 mA Current Output Capability
MIL-STD-883 Compliant Versions Available

PIN CONFIGURATIONS

8-Pin TO-99



8-Pin DIP



GENERAL DESCRIPTION

The AD584 is an eight-terminal precision voltage reference offering pin-programmable selection of four popular output voltages: 10.000 V, 7.500 V, 5.000 V and 2.500 V. Other output voltages, above, below or between the four standard outputs, are available by the addition of external resistors. Input voltage may vary between 4.5 and 30 volts.

Laser Wafer Trimming (LWT) is used to adjust the pin-programmable output levels and temperature coefficients, resulting in the most flexible high precision voltage reference available in monolithic form.

In addition to the programmable output voltages, the AD584 offers a unique strobe terminal which permits the device to be turned on or off. When the AD584 is used as a power supply reference, the supply can be switched off with a single, low-power signal. In the "off" state the current drain by the AD584 is reduced to about 100 µA. In the "on" state the total supply current is typically 750 µA including the output buffer amplifier.

The AD584 is recommended for use as a reference for 8-, 10- or 12-bit D/A converters which require an external precision reference. The device is also ideal for all types of A/D converters of up to 14-bit accuracy, either successive approximation or integrating designs, and in general can offer better performance than that provided by standard self-contained references.

The AD584J, K and L are specified for operation from 0°C to +70°C; the AD584S and T are specified for the –55°C to +125°C range. All grades are packaged in a hermetically sealed eight-terminal TO-99 metal can; the AD584 J and K are also available in an 8-pin plastic DIP.

***Protected by U.S. Patent No. 3,887,863; RE 30,586**

PRODUCT HIGHLIGHTS

1. The flexibility of the AD584 eliminates the need to design-in and inventory several different voltage references. Furthermore one AD584 can serve as several references simultaneously when buffered properly.
2. Laser trimming of both initial accuracy and temperature coefficient results in very low errors over temperature without the use of external components. The AD584LH has a maximum deviation from 10.000 volts of ±7.25 mV from 0°C to +70°C.
3. The AD584 can be operated in a two-terminal "Zener" mode at 5 volts output and above. By connecting the input and the output, the AD584 can be used in this "Zener" configuration as a negative reference.
4. The output of the AD584 is configured to sink or source currents. This means that small reverse currents can be tolerated in circuits using the AD584 without damage to the reference and without disturbing the output voltage (10 V, 7.5 V and 5 V outputs).
5. The AD584 is available in versions compliant with MIL-STD-883. Refer to the Analog Devices Military Products Databook or current AD584/883B data sheet for detailed specifications.

REV. A

One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106, U.S.A.
Tel: 617/329-4700 Fax: 617/326-8703

Model	AD584J Min	AD584J Typ	AD584J Max	AD584K Min	AD584K Typ	AD584K Max	AD584L Min	AD584L Typ	AD584L Max	Units
OUTPUT VOLTAGE TOLERANCE										
Maximum Error[1] for Nominal										
Outputs of:										
10.000 V			**±30**			**±10**			**±5**	mV
7.500 V			**±20**			**±8**			**±4**	mV
5.000 V			**±15**			**±6**			**±3**	mV
2.500 V			**±7.5**			**±3.5**			**±2.5**	mV
OUTPUT VOLTAGE CHANGE										
Maximum Deviation from +25°C										
Value, T_{MIN} to T_{MAX}[2]										
10.000 V, 7.500 V, 5.000 V Outputs			**30**			**15**			**5**	ppm/°C
2.500 V Output			**30**			**15**			**10**	ppm/°C
Differential Temperature										
Coefficients Between Outputs		5			3			3		ppm/°C
QUIESCENT CURRENT		0.75	**1.0**		0.75	**1.0**		0.75	**1.0**	mA
Temperature Variation		1.5			1.5			1.5		µA/°C
TURN-ON SETTLING TIME TO 0.1%		200			200			200		µs
NOISE										
(0.1 Hz to 10 Hz)		50			50			50		µV p-p
LONG-TERM STABILITY		25			25			25		ppm/1000 Hrs
SHORT-CIRCUIT CURRENT		30			30			30		mA
LINE REGULATION (No Load)										
15 V ≤ V_{IN} ≤ 30 V			**0.002**			**0.002**			**0.002**	%/V
(V_{OUT} +2.5 V) ≤ V_{IN} ≤ 15 V			**0.005**			**0.005**			**0.005**	%/V
LOAD REGULATION										
0 ≤ I_{OUT} ≤ 5 mA, All Outputs		20	**50**		20	**50**		20	**50**	ppm/mA
OUTPUT CURRENT										
V_{IN} ≥ V_{OUT} +2.5 V										
Source @ +25°C	10			10			10			mA
Source T_{MIN} to T_{MAX}	5			5			5			mA
Sink T_{MIN} to T_{MAX}	5			5			5			mA
TEMPERATURE RANGE										
Operating	0		+70	0		+70	0		+70	°C
Storage	–65		+175	–65		+175	–65		+175	°C
PACKAGE OPTION[3]										
TO-99 (H-08A)		AD584JH			AD584KH			AD584LH		
Plastic (N-8)		AD584JN			AD584KN					

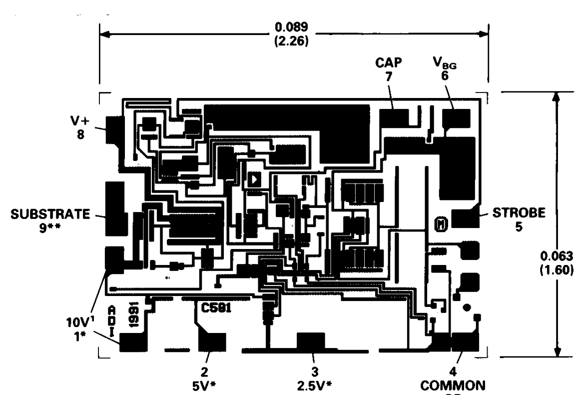
NOTES
[1]At Pin 1.
[2]Calculated as average over the operating temperature range.
[3]H = Hermetic Metal Can; N = Plastic DIP.
Specifications subject to change without notice.
Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

ABSOLUTE MAXIMUM RATINGS

Input Voltage V_{IN} to Ground . . . . 40 V
Power Dissipation @ +25°C . . . . 600 mW
Operating Junction Temperature Range . . . .–55°C to +125°C
Lead Temperature (Soldering 10 sec) . . . . +300°C
Thermal Resistance
Junction-to-Ambient (H-08A) . . . . 150°C/W

METALIZATION PHOTOGRAPH

Dimensions shown in inches and (mm).



NOTES
[1]BOTH 10V PADS MUST BE CONNECTED TO THE OUTPUT.
*INTERCONNECTIONS REQUIRED; SEE PIN DESIGNATIONS FOR INFORMATION.
**NOT BROUGHT OUT IN PACKAGE DEVICE.
PAD NUMBERS CORRESPOND TO PIN NUMBERS FOR THE TO-99, 8-PIN METAL PACKAGE.

Model	AD584S Min	AD584S Typ	AD584S Max	AD584T Min	AD584T Typ	AD584T Max	Units
OUTPUT VOLTAGE TOLERANCE							
Maximum Error[1] for Nominal							
Outputs of:							
10.000 V			**±30**			**±10**	mV
7.500 V			**±20**			**±8**	mV
5.000 V			**±15**			**±6**	mV
2.500 V			**±7.5**			**±3.5**	mV
OUTPUT VOLTAGE CHANGE							
Maximum Deviation from +25°C							
Value, T_{MIN} to T_{MAX}[2]							
10.000 V, 7.500 V, 5.000 V Outputs			**30**			**15**	ppm/°C
2.500 V Output			**30**			**20**	ppm/°C
Differential Temperature							
Coefficients Between Outputs		5			3		ppm/°C
QUIESCENT CURRENT		0.75	**1.0**		0.75	**1.0**	mA
Temperature Variation		1.5			1.5		µA/°C
TURN-ON SETTLING TIME TO 0.1%		200			200		µs
NOISE							
(0.1 Hz to 10 Hz)		50			50		µV p-p
LONG-TERM STABILITY		25			25		ppm/1000 Hrs
SHORT-CIRCUIT CURRENT		30			30		mA
LINE REGULATION (No Load)							
$15\text{ V} \le V_{IN} \le 30\text{ V}$			**0.002**			**0.002**	%/V
$(V_{OUT} + 2.5\text{ V}) \le V_{IN} \le 15\text{ V}$			**0.005**			**0.005**	%/V
LOAD REGULATION							
$0 \le I_{OUT} \le 5$ mA, All Outputs		20	**50**		20	**50**	ppm/mA
OUTPUT CURRENT							
$V_{IN} \ge V_{OUT} + 2.5\text{ V}$							
Source @ +25°C	10			10			mA
Source T_{MIN} to T_{MAX}	5			5			mA
Sink T_{MIN} to T_{MAX}	5			5			mA
TEMPERATURE RANGE							
Operating	–55		+125	–55		+125	°C
Storage	–65		+175	–65		+175	°C
PACKAGE OPTION							
TO-99 (H-08A)		AD584SH			AD584TH		

NOTES
[1]At Pin 1.
[2]Calculated as average over the operating temperature range.
Specifications subject to change without notice.
Specifications shown in boldface are tested on all production units at final electrical test. Results from those tests are used to calculate outgoing quality levels. All min and max specifications are guaranteed, although only those shown in boldface are tested on all production units.

APPLYING THE AD584

With power applied to Pins 8 and 4 and all other pins open, the AD584 will produce a buffered nominal 10.0 V output between Pins 1 and 4 (see Figure 1). The stabilized output voltage may be reduced to 7.5 V, 5.0 V or 2.5 V by connecting the programming pins as follows:

Output Voltage	Pin Programming
7.5 V	Join the 2.5 V and 5.0 V pins (2) and (3)
5.0 V	Connect the 5.0 V pin (2) to the output pin (1).
2.5 V	Connect the 2.5 V pin (3) to the output pin (1).

The options shown above are available without the use of any additional components. Multiple outputs using only one AD584, are also possible by simply buffering each voltage programming pin with a unity-gain noninverting op amp.

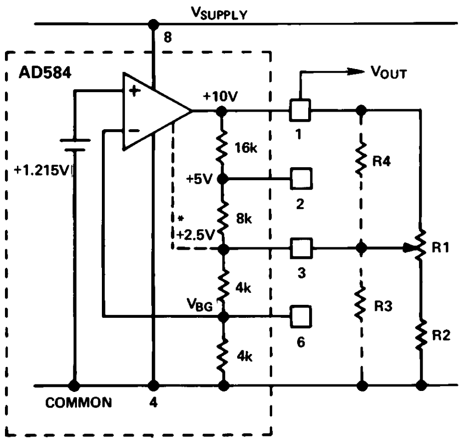


Figure 1. Variable Output Options

The AD584 can also be programmed over a wide range of output voltages, including voltages greater than 10 V, by the addition of one or more external resistors. Figure 1 illustrates the general adjustment procedure, with approximate values given for the internal resistors of the AD584. The AD584 may be modeled as an op amp with a noninverting feedback connection, driven by a high stability 1.215 volt bandgap reference (see Figure 3 for schematic).

When the feedback ratio is adjusted with external resistors, the output amplifier can be made to multiply the reference voltage by almost any convenient amount, making popular outputs of 10.24 V, 5.12 V, 2.56 V or 6.3 V easy to obtain. The most general adjustment (which gives the greatest range and poorest resolution) uses R1 and R2 alone (see Figure 1). As R1 is adjusted to its upper limit the 2.5 V Pin 3 will be connected to the output, which will reduce to 2.5 V. As R1 is adjusted to its lower limit, the output voltage will rise to a value limited by R2. For example, if R2 is about 6 kΩ, the upper limit of the output range will be about 20 V even for large values of R1. R2 should not be omitted; its value should be chosen to limit the output to a value which can be tolerated by the load circuits. If R2 is zero, adjusting R1 to its lower limit will result in a loss of control over the output voltage. If precision voltages are required to be set at levels other than the standard outputs, the 20% absolute tolerance in the internal resistor ladder must be accounted for.

Alternatively, the output voltage can be raised by loading the 2.5 V tap with R3 alone. The output voltage can be lowered by connecting R4 alone. Either of these resistors can be a fixed resistor selected by test or an adjustable resistor. In all cases the resistors should have a low temperature coefficient to match the AD584 internal resistors, which have a negative T.C. less than 60 ppm/°C. If both R3 and R4 are used, these resistors should have matched temperature coefficients.

When only small adjustments or trims are required, the circuit of Figure 2 offers better resolution over a limited trim range. The circuit can be programmed to 5.0 V, 7.5 V or 10 V and adjusted by means of R1 over a range of about ±200 mV. To trim the 2.5 V output option, R2 (Figure 2) can be reconnected to the bandgap reference (Pin 6). In this configuration, the adjustment should be limited to ±100 mV in order to avoid affecting the performance of the AD584.

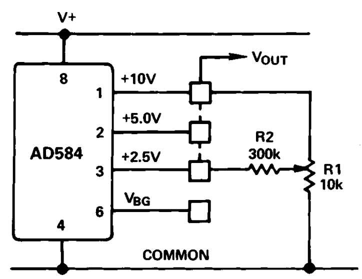


Figure 2. Output Trimming

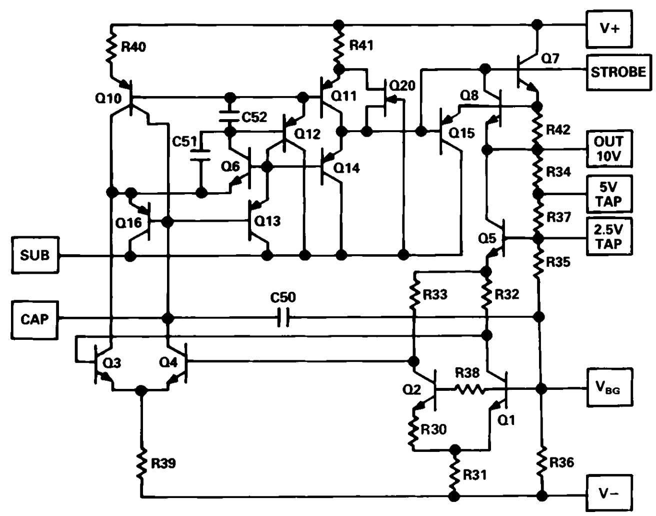


Figure 3. Schematic Diagram

PERFORMANCE OVER TEMPERATURE

Each AD584 is tested at three temperatures over the –55°C to +125°C range to ensure that each device falls within the Maximum Error Band (see Figure 4) specified for a particular grade (i.e., S and T grades); three-point measurement guarantees performance within the error band from 0°C to +70°C (i.e., J, K, or L grades). The error band guaranteed for the AD584 is the maximum deviation from the initial value at +25°C. Thus, given the grade of the AD584, the designer can easily determine the maximum total error from initial tolerance plus temperature variation. For example, for the AD584T, the initial tolerance is ±10 mV and the error band is ±15 mV. Hence, the unit is guaranteed to be 10.000 volts ±25 mV from –55°C to +125°C.

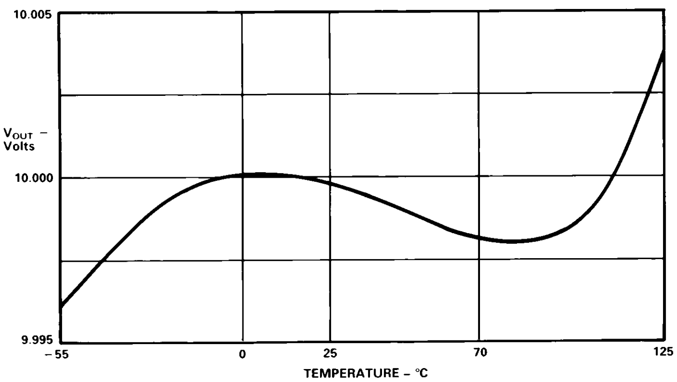


Figure 4. Typical Temperature Characteristic

OUTPUT CURRENT CHARACTERISTICS

The AD584 has the capability to either source or sink current and provide good load regulation in either direction, although it has better characteristics in the source mode (positive current into the load). The circuit is protected for shorts to either positive supply or ground. The output voltage vs. output current characteristics of the device is shown in Figure 5. Source current is displayed as negative current in the figure; sink current is positive. Note that the short circuit current (i.e., zero volts output) is about 28 mA; when shorted to +15 volts, the sink current goes to about 20 mA.

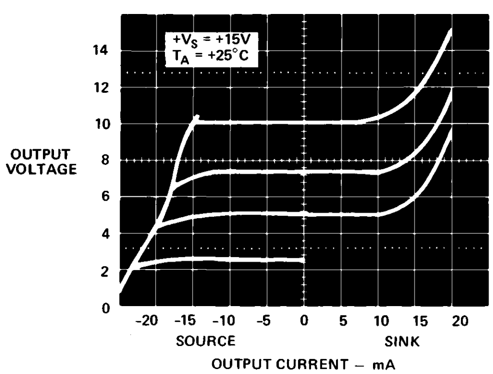


Figure 5. AD584 Output Voltage vs. Sink and Source Current

DYNAMIC PERFORMANCE

Many low power instrument manufacturers are becoming increasingly concerned with the turn-on characteristics of the components being used in their systems. Fast turn-on components often enable the end user to keep power off when not needed, and yet respond quickly when the power is turned on for operation. Figure 6 displays the turn-on characteristic of the AD584. Figure 6a is generated from cold-start operation and represents the true turn-on waveform after an extended period with the supplies off. The figure shows both the coarse and fine transient characteristics of the device; the total settling time to within ±10 millivolt is about 180 µs, and there is no long thermal tail appearing after the point.

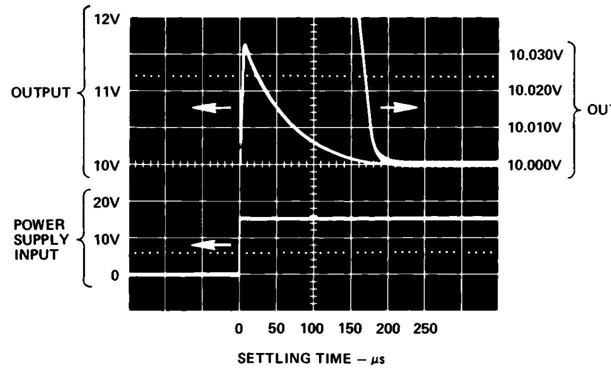


Figure 6. Output Settling Characteristic

NOISE FILTERING

The bandwidth of the output amplifier in the AD584 can be reduced to filter the output noise. A capacitor ranging between 0.01 µF and 0.1 µF connected between the Cap and V_{BG} terminals will further reduce the wideband and feedthrough noise in the output of the AD584, as shown in Figure 8. However, this will tend to increase the turn-on settling time of the device so ample warm-up time should be allowed.

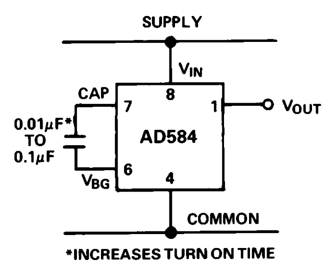


Figure 7. Additional Noise Filtering with an External Capacitor

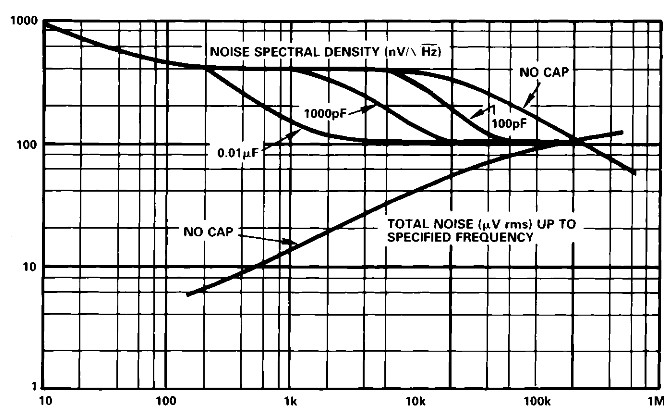


Figure 8. Spectral Noise Density and Total rms Noise vs. Frequency

USING THE STROBE TERMINAL

The AD584 has a strobe input which can be used to zero the output. This unique feature permits a variety of new applications in signal and power conditioning circuits.

Figure 9 illustrates the strobe connection. A simple NPN switch can be used to translate a TTL logic signal into a strobe of the output. The AD584 operates normally when there is no current drawn from Pin 5. Bringing this terminal low, to less than 200 mV, will allow the output voltage to go to zero. In this mode the AD584 should not be required to source or sink current (unless a 0.7 V residual output is permissible). If the AD584 is required to sink a transient current while strobed off, the strobe terminal input current should be limited by a 100 Ω resistor as shown in Figure 9.

The strobe terminal will tolerate up to 5 µA leakage and its driver should be capable of sinking 500 µA continuous. A low leakage open collector gate can be used to drive the strobe terminal directly, provided the gate can withstand the AD584 output voltage plus one volt.

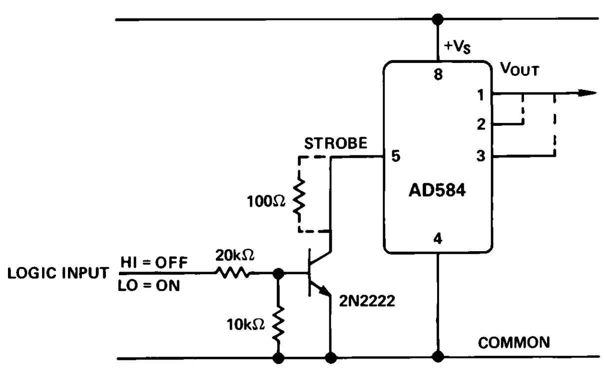


Figure 9. Use of the Strobe Terminal

PRECISION HIGH CURRENT SUPPLY

The AD584 can be easily connected to a power PNP or power Darlington PNP device to provide much greater output current capability. The circuit shown in Figure 10 delivers a precision 10 volt output with up to 4 amperes supplied to the load. The 0.1 µF capacitor is required only if the load has a significant capacitive component. If the load is purely resistive, improved high frequency supply rejection results from removing the capacitor.

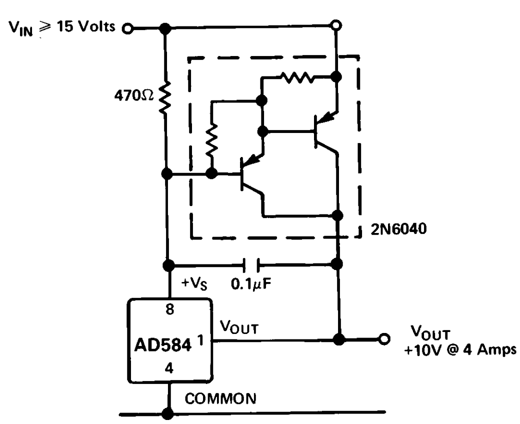


Figure 10. High Current Precision Supply

The AD584 can also use an NPN or Darlington NPN transistor to boost its output current. Simply connect the 10 V output terminal of the AD584 to the base of the NPN booster and take the output from the booster emitter as shown in Figure 11. The 5.0 V or 2.5 V pin must connect to the actual output in this configuration. Variable or adjustable outputs (as shown in Figures 1 and 2) may be combined with +5.0 V connection to obtain outputs above +5.0 V.

THE AD584 AS A CURRENT LIMITER

The AD584 represents an alternative to current limiter diodes which require factory selection to achieve a desired current. Use of current limiting diodes often results in temperature coefficients of 1%/°C. Use of the AD584 in this mode is not limited to a set current limit; it can be programmed from 0.75 mA to 5 mA with the insertion of a single external resistor (see Figure 12). Of course, the minimum voltage required to drive the connection is 5 volts.

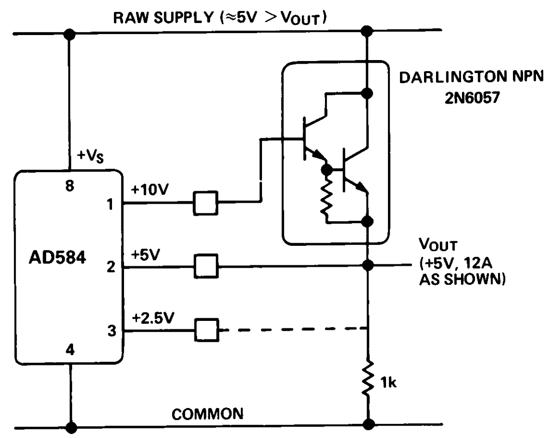


Figure 11. NPN Output Current Booster

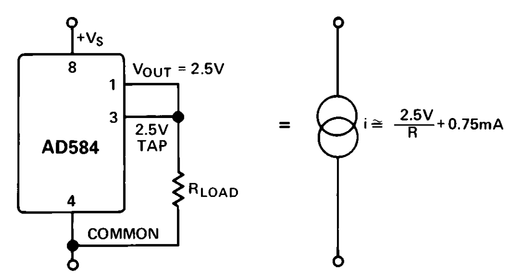


Figure 12. A Two-Component Precision Current Limiter

NEGATIVE REFERENCE VOLTAGES FROM AN AD584

The AD584 can also be used in a two-terminal "Zener" mode to provide a precision –10 volt, –7.5 volt or –5.0 volt reference. As shown in Figure 13, the V_{IN} and V_{OUT} terminals are connected together to the positive supply (in this case, ground). The AD584 common pin is connected through a resistor to the negative supply. The output is now taken from the common pin instead of V_{OUT}. With 1 mA flowing through the AD584 in this mode, a typical unit will show a 2 mV increase in output level over that produced in the three-terminal mode. Note also that the effective output impedance in this connection increases from 0.2 Ω typical to 2 Ω. It is essential to arrange the output load and the supply resistor, R_S, so that the net current through the AD584 is always between 1 mA and 5 mA (between 2 mA and 5 mA for operation beyond +85°C). The temperature character-

istics and long-term stability of the device will be essentially the same as that of a unit used in the standard three-terminal mode.

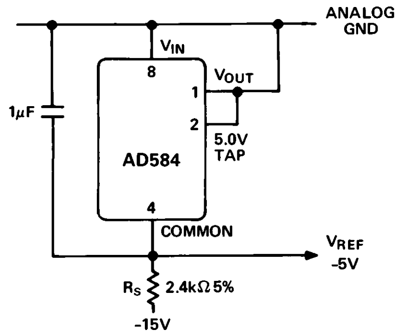


Figure 13. Two-Terminal –5 Volt Reference

The AD584 can also be used in a two-terminal mode to develop a positive reference. V_{IN} and V_{OUT} are tied together and to the positive supply through an appropriate supply resistor. The performance characteristics will be similar to those of the negative two-terminal connection. The only advantage of this connection over the standard three-terminal connection is that a lower primary supply can be used, as low as 0.5 volts above the desired output voltage. This type of operation will require considerable attention to load and primary supply regulation to be sure the AD584 always remains within its regulating range of 1 mA to 5 mA (2 mA to 5 mA for operation beyond 85°C).

10 VOLT REFERENCE WITH MULTIPLYING CMOS D/A OR A/D CONVERTERS

The AD584 is ideal for application with the entire AD7520 series of 10- and 12-bit multiplying CMOS D/A converters, especially for low power applications. It is equally suitable for the AD7574 8-bit A/D converter. In the standard hook-up as shown in Figure 14, the standard output voltages are inverted by the amplifier/DAC configuration to produce converted voltage ranges. For example, a +10 V reference produces a 0 V to –10 V range. If an AD308 amplifier is used, total quiescent supply current will typically be 2 mA. The AD584 will normally be used in the –10 volt mode with the AD7574 to give a 0 volt to +10 volt ADC range. This is shown in Figure 16. Bipolar output applications and other operating details can be found in the data sheets for the CMOS products.

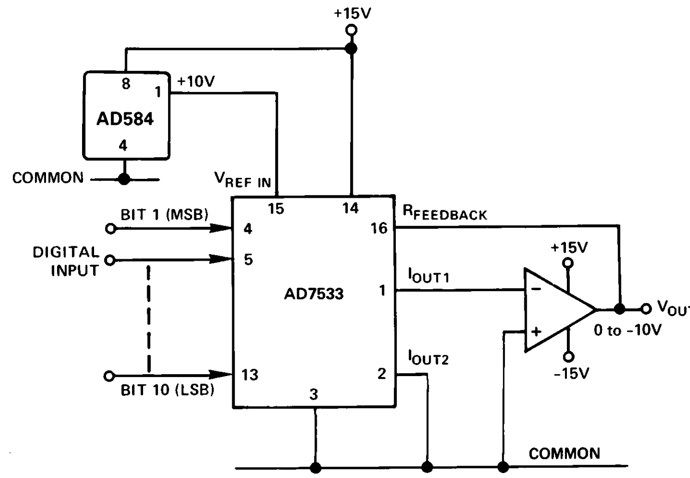


Figure 14. Low Power 10-Bit CMOS DAC Application

PRECISION D/A CONVERTER REFERENCE

The AD562, like many D/A converters, is designed to operate with a +10 volt reference element (Figure 15). In the AD562, this 10 volt reference voltage is converted into a reference current of approximately 0.5 mA via the internal 19.95 kΩ resistor (in series with the external 100 Ω trimmer). The gain temperature coefficient of the AD562 is primarily governed by the temperature tracking of the 19.95 kΩ resistor and the 5k/10k span resistors; this gain T.C. is guaranteed to 3 ppm/°C. Thus, using the AD584L (at 5 ppm/°C) as the 10 volt reference guarantees a

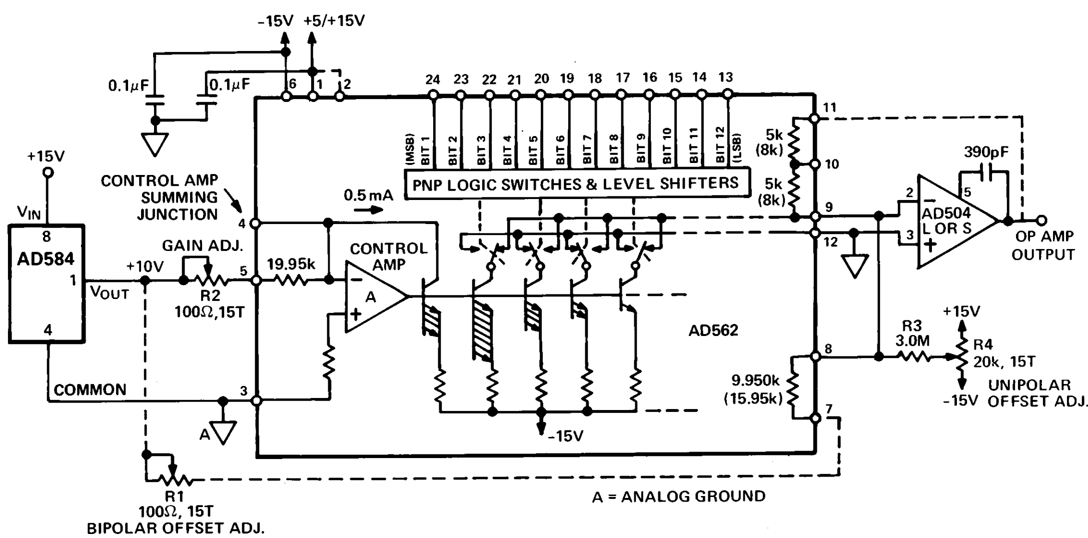


Figure 15. Precision 12-Bit D/A Converter

maximum full scale temperature coefficient of 8 ppm/°C over the commercial range. The 10 volt reference also supplies the normal 1 mA bipolar offset current through the 9.95k bipolar offset resistor. The bipolar offset T.C. thus depends only on the T.C. matching of the bipolar offset resistor to the input reference resistor and is guaranteed to 3 ppm/°C. Figure 17 demonstrates the flexibility of the AD584 applied to another popular D/A configuration.

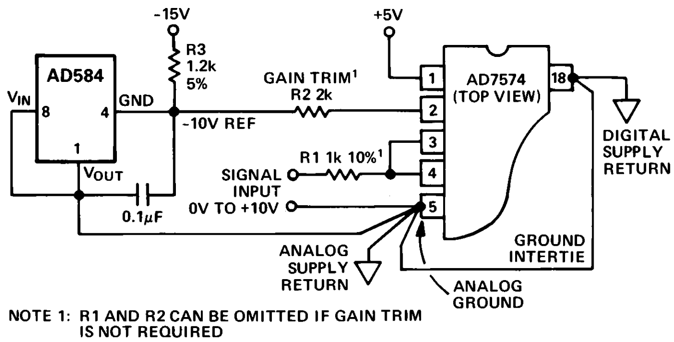


Figure 16. AD584 as Negative 10 Volt Reference for CMOS ADC

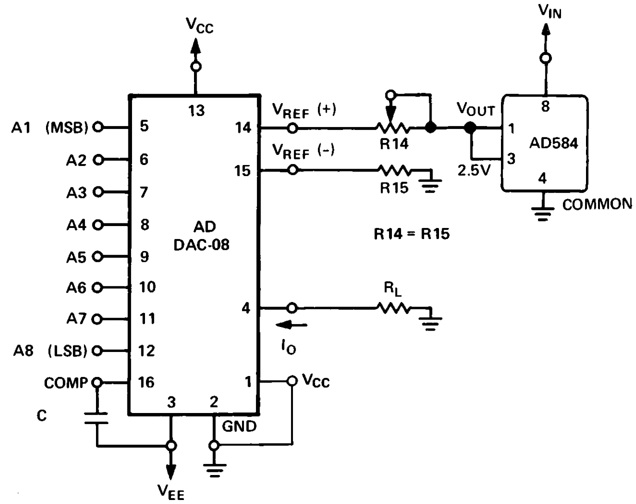


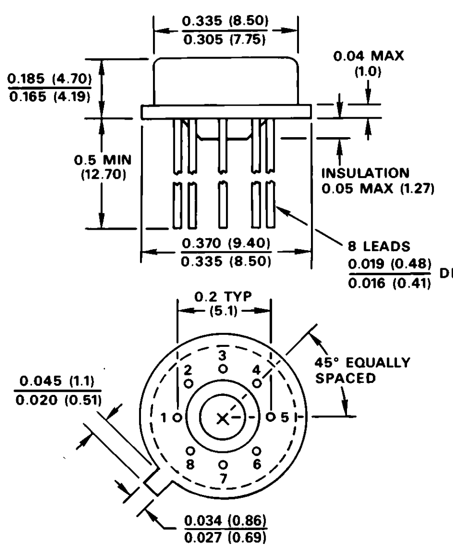
Figure 17. Current Output 8-Bit D/A

C473e–10–6/86

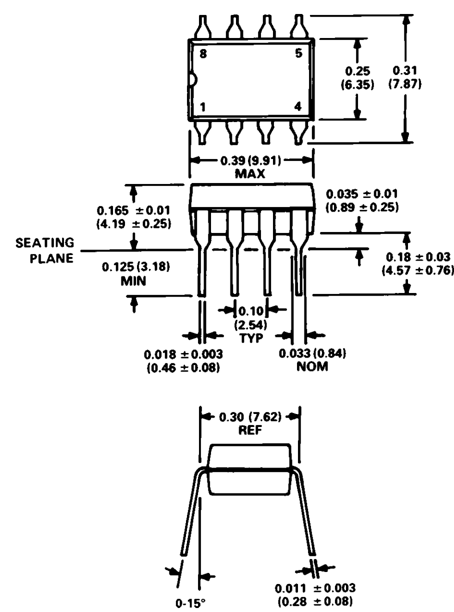
OUTLINE DIMENSIONS

Dimensions shown in inches and (mm).

TO-99 (H) Package



Plastic DIP (N) Package



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